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REPORT NO. DPS/TS1-200/21

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INFANTRY AND AIRCRAFT WEAPONS DIVISION

REPORT ON

SURVEY OF THE EFFECTIVENESS OF BLAST MINES AND EXPLOSIVE CHARGES AGAINST TANKS (U)

21st Report on Ordnance Project No. TS1-200

(D. A. Project No. 507-06-011)

P. E. KERTIS

APRIL 1960

Aberdeen Proving Ground
Maryland

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MARYLAND

AUTHORITY: ORDBB-TF3
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SURVEY OF THE EFFECTIVENESS OF BLAST MINES AND EXPLOSIVE CHARGES AGAINST TANKS (U)

Twenty-First Report on Ordnance Project No. TS1-200

Dates of Test: 1 October 1959 to 29 March 1960

ABSTRACT (U)

An extensive library search was conducted to compile data from tests involving tank vulnerability to high-explosive-blast attack. An analytical study of these data produced information which will enable mine designers to make the most efficient choice of explosive weights and permit a detailed comparison of complete-round effectiveness.

CONTENTS (U)

1. (U) INTRODUCTION

During the past ten years many tests have been conducted involving tanks and high-explosive mines. Some measured the vulnerability of the vehicle, or its components, to blast-mine attack. Others sought to determine the effectiveness of the explosive charges, in the form of mines, against the vehicles. A few existing reports specifically predicted the damage to be expected when a certain tank encountered a given mine, but these were limited and incomplete. It is the aim of this program to consolidate and present all the available data in a form that will permit accurate prediction of the damage which will result from the detonation of a given weight of explosive against a tank. Such information will greatly aid mine designers in making the most efficient and economical choice of explosive-charge, weights and fuze-functioning characteristics. This information is particularly desired in connection with a current feasibility study of remotely emplaced mine systems.

2. (U) MATERIEL

2.1 Explosive Charges

The explosive charges studied, listed by increasing weight, are briefly described as follows:

2.5- to 10-lb	-	Composition B, HBX6, or TNT - galvanized steel containers with plywood bases.
3.5-lb	-	Tetrytol - M7 Mine.
12-lb	-	Composition B, or TNT - M6 Mine.
20- to 22-lb	-	TNT - Bare charges.
24-lb	-	Comp B or TNT - Two M6 mines positioned base to base.
35-lb	-	Comp B - An M15 and M6 Mine positioned base to base.
40-lb	-	TNT - Bare charge.
44-lb	-	Comp B - Two M15 mines positioned base to base.
54- to 216-lb	-	TNT - Cast 27-lb discs in multiples of 2, 4 or 8.

2.2 Target Tanks

The tanks used for these tests were:

United States	-	M4, M26 - T26, M47, M48 - T48.
Soviet	-	T34/85.
German	-	Panther.
United States	-	M47 fitted with Soviet JS III Track.

The widths of the types of track encountered were:

United States double-pin	- 23 inches.
United States single-pin	- 24 inches.
Soviet T34/85	- 20 inches.
Soviet JS III	- 25-1/4 inches.
German Panther	- 25 inches.

3. (U) METHOD OF APPROACH

3.1 Damage Echelons

The first problem was to categorize the available information in terms of damage levels that would constitute successful mine attacks.

3.1.1 Echelon "A". Since a tank loses much of its effectiveness if it cannot move, and since its mobility was most affected by track breakage, this was chosen as the minimum successful damage. This was called Damage Echelon "A" and is summarized as: "Target immobilized by track breakage - reparable by crew in field." The facts that the crew and the firepower of the tank are virtually unaffected, and that the damage is reparable by the crew in a short period of time, were not considered. The primary objective is to halt the vehicle for some period of time.

3.1.2 Echelon "B". A second degree of immobilization damage was more severe. It included all suspension damage greater than track breakage that was still reparable. However, most of the repairs could not be performed by the crew. Damage Echelon "B" is summarized as: "Target immobilized by severe suspension damage - reparable only in a rear-area repair shop."

3.1.3 Echelon "C". The third degree of damage renders the tank completely useless and unreparable. Vehicle overturning is included in this category by definition. This is Damage Echelon "C" and is summarized as: "Target destroyed - damage irreparable." The possibility of damage by fire was not considered.

3.1.4 Objectives. Using these damage echelons, three specific objectives were sought:

a. A minimum weight of explosive that will immobilize the tank.

b. A minimum weight of explosive that will severely damage the hull.

c. The weights of explosive required to produce overturning or complete destruction.

3.2 Other Parameters Considered

An explanation of the other parameters considered follows:

3.2.1 Target Type. The target type included the model number of the tank and, in the case of US tanks, a notation of the type of track, e.g., single-pin or double-pin.

3.2.2 Explosive Weight. Explosive weight was measured in pounds, but does not include the weight of the casing of mines.

3.2.3 Standoff Distance. Standoff distance was measured in inches from two different origins. For light charges up to and including 24 pounds, the measurement was the perpendicular distance between the longitudinal track centerline and the center of the explosive charge (see Figure 1).

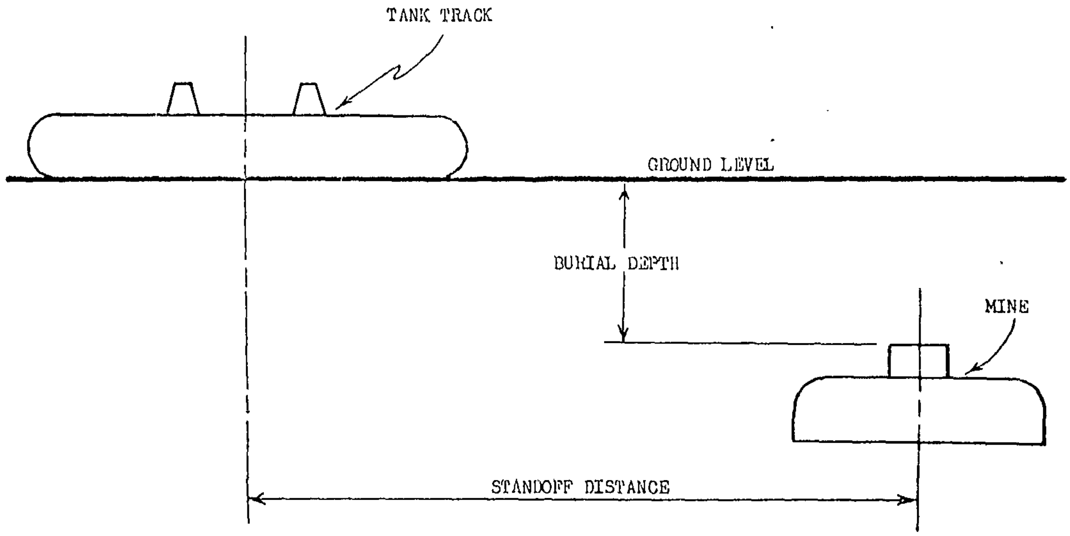

Figure 1: Depth and Standoff Measurements For Charges of 24 Pounds or Less.

For charges exceeding 24 pounds, where vehicle overturning was the rule rather than the exception, the standoff measurement was the horizontal distance between the tank hull longitudinal centerline and the center of the charge (see Figure 2).

3.2.4 Burial Depth. The burial depth was also measured in inches from two different origins depending on the charge weight. Again, for charges up to and including 24 pounds, the burial depth was the measurement of the amount of earth covering the top of the charge (see Figure 1). This is standard procedure for mines.

For the heavy charges, the depth was measured from ground level to the center of gravity of the charge (see Figure 2).

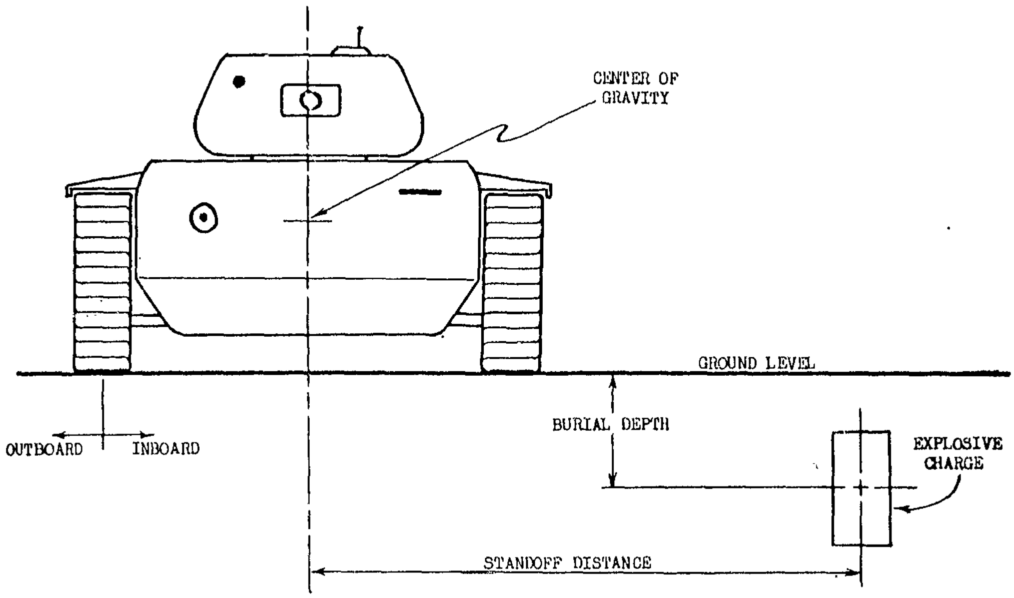

Figure 2: Depth and Standoff Measurements for Charges Exceeding 24 Pounds.

3.2.5 Charge Position. The location of the charge in relation to the tank was determined by two factors: lateral position and longitudinal position. Lateral position refers to either "Inboard" or "Outboard," each relative to the center lines of the tracks. Longitudinal position was determined by the number of the road wheel with which the charge was aligned, or the numbers of the road wheels between which the charge was centered.

3.2.6. Soil Condition. One significant variable, soil condition, had to be neglected. The soil condition had been recorded by many proof directors, but each used his own terminology and set of values. This produced approximately 20 different nomenclatures with no means for accurately grouping them.

The explosive type was considered only for the small charges. In practically all instances, the heavy charges were either Composition B or TNT, which appear to be approximately equal in effectiveness.

4. RESULTS

4.1 Greater Than 24-Pound Class

(U) The data as presented for analysis were separated by weight of explosive into three groups. This first group contained the heavy charges capable of overturning a tank or causing complete destruction. Weights ranged from the 35-pound M15/M6 mine to a 216-pound, cast-TNT charge. Details are contained in Analytical Laboratory Report Number 60-AL-26, Appendix B.

(U) It was hoped that the data in their final form would indicate the combination of weight, standoff and depth that will produce immobilizations 100 per cent of the time. This is not the case. The data for these heavy charges are quite sparse, and at best they indicate the maximum standoff and depth combination at which some immobilizations will occur. Therefore, in the final analysis, each successful charge will be considered, thereby producing a range in which some immobilizations can be expected to occur.

(C) Nine mines in the 35-pound weight group were fired. The only successful immobilizations were obtained at a standoff of 64 inches. The burial depths varied from 10 to 30 inches. All were fired outboard of the tank, but it is assumed this weight of explosive will successfully defeat the tank-belly armor over its entire width. Therefore, a 35-pound charge will immobilize a tank at standoff distances to 64 inches and depths from 10 to 30 inches (see Figure 3).

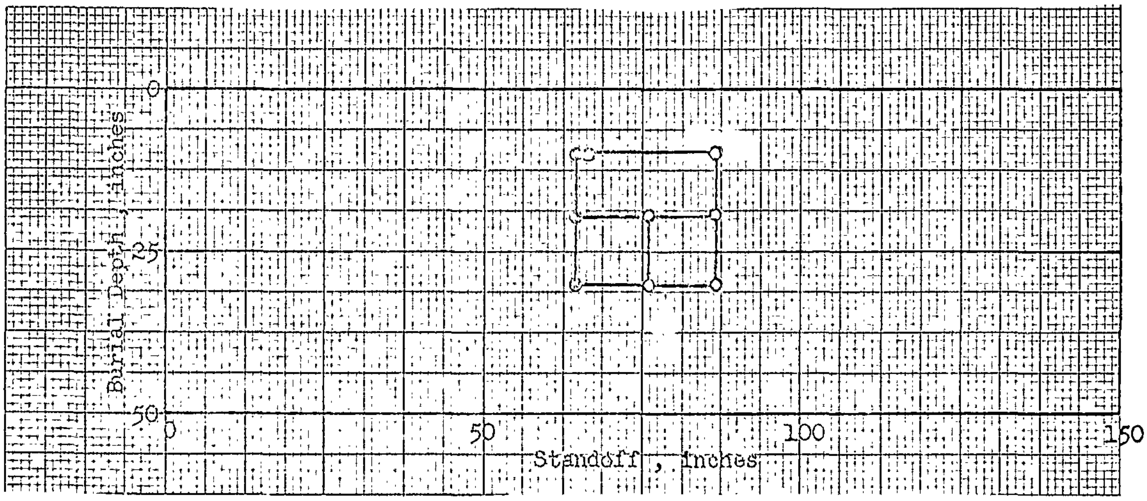

Figure 3 (C): Depth Versus Standoff - 35-Pound Charges.
Ø = Immobilization.
0 = Non-immobilization.

(C) A total of eleven 40-pound charges was fired, four of these under the centerline of the tank. These four inboard charges immobilized the targets, thereby substantiating the assumption that 35 pounds will also defeat the belly armor. Outboard, seven attempts produced three immobilizations. The conditions that produced these successes were: 93-inch standoff and 31-inch burial; 77- and 93-inch standoffs, both at 44-inch burials. These three conditions will be considered in the final analysis (see Figure 4).

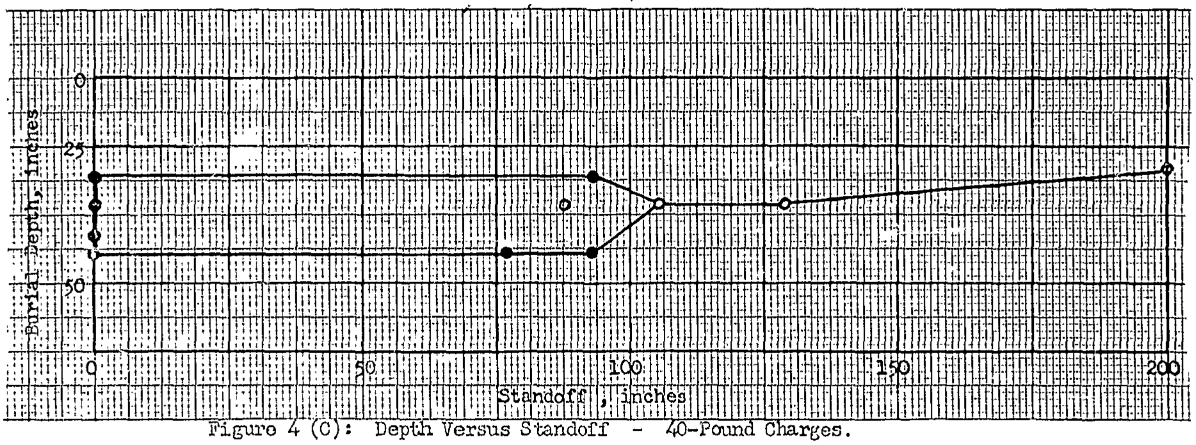

Figure 4 (C): Depth Versus Standoff - 40-Pound Charges.

o = Immobilization.
O = Non-immobilization.

(C) Only five 46-pound charges were detonated at two standoffs and three burial depths. The conditions at which successful immobilizations occurred were: 88-inch standoff and 30-inch burial; 88- and 100-inch standoffs, both at 20-inch burial depths (see Figure 5).

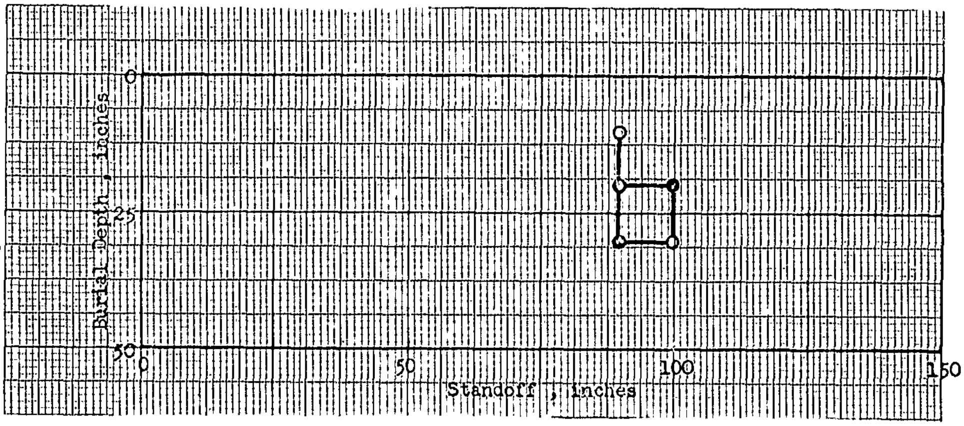

Figure 5 (C): Depth Versus Standoff - 46-Pound Charges.

o = Immobilization.
O = Non-immobilization.

(C) A total of 15 charges of 108 pounds were fired, excluding the one unsuccessful attempt at the extreme 97-inch burial depth. The other charges were all emplanted to depths of either 63 or 65 inches. At the 63-inch burial, the maximum standoff for immobilization was 132 inches. However, this immobilization (Damage Echelon "B") was not due to overturning. The maximum overturning standoff was 120 inches. At a burial depth of 65 inches the maximum standoff was 102 inches, and the immobilization was due to overturning. These three conditions will be considered in the final analysis.

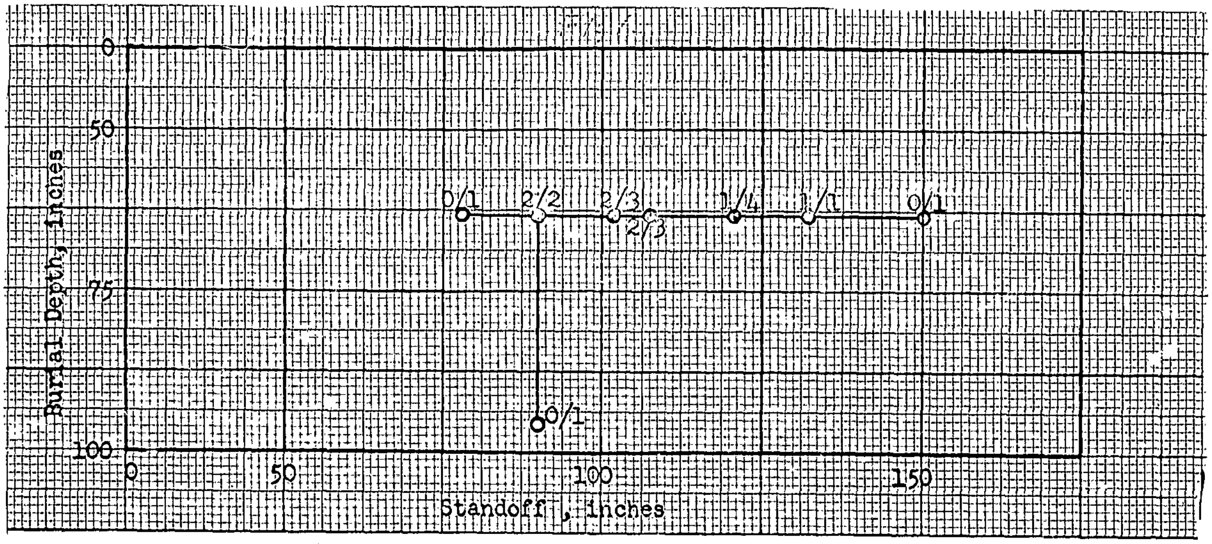

Figure 6 (C): Depth Versus Standoff - 108-Pound Charges.
0 = Immobilization. O = Non-immobilization.

(C) A total of 11 charges was fired in the 216-pound weight group, and five produced immobilizations. A distinct pattern is clearly noticeable with this weight group. It defines the line separating the will-immobilize positions from the will-nots. The combinations of standoff and depth at which some immobilizations will occur are: 72-inch depth - 138- and 150-inch standoffs; 81-inch depth - 132-inch standoff; 96-inch depth - 96-inch standoff.

(U) It must be remembered that these standoffs are the maximum distances at which immobilizations are known to have occurred. Nothing can be concluded concerning the probability of immobilizations.

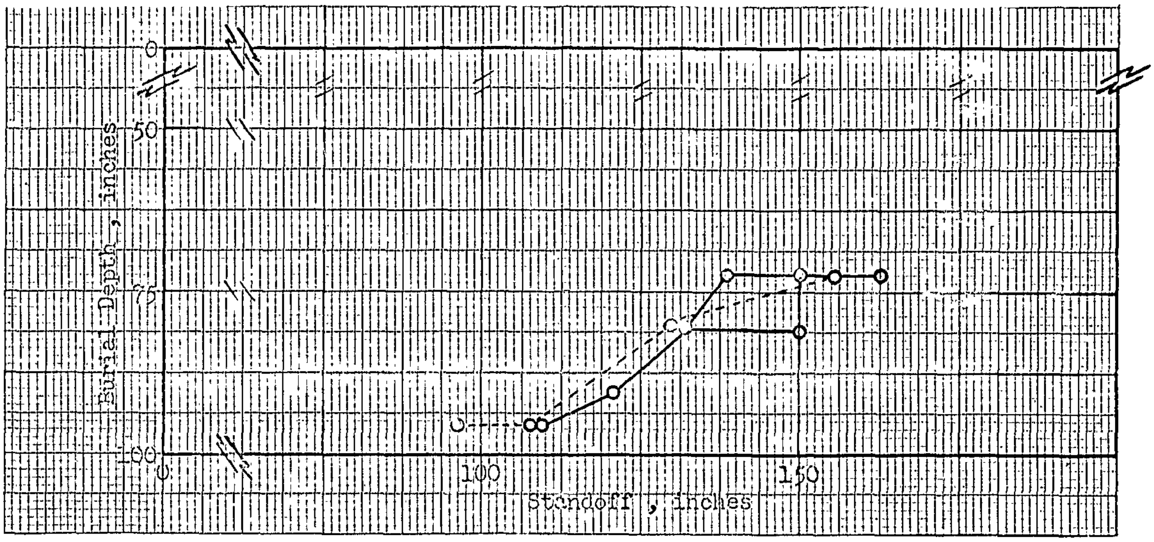

Figure 7 (C): Depth Versus Standoff - 216-Pound Charges.
0 = Immobilization.
0 = Non-immobilization.

4.2 Twelve- to 24-Pound Class

(U) The second group contained the 12- and 24-pound charges which were single and double M6 mines. Details are contained in Analytical Laboratory Report Number 60-AL-19, Appendix C.

(U) Charges of these weights are mainly effective against the tank track. Therefore standoff distances are measured from the charge to the centerline of the track. The maximum standoff, where immobilizations occur 100 per cent of the time, generally differs inboard and outboard. For this analysis, only the lesser of the two, the outboard distance, is considered.

(C) By reference to Charts 1, 3 and 4 in Analytical Laboratory Report Number 60-AL-19 (Appendix C), the maximum standoff distances can be read directly. The distance is read on the abscissa at the point where the curve intersects the "100 per cent of tanks immobilized" line. The distances, weights and track types are:

12 in.	12 lb	Double pin
17 in.	24 lb	Double pin
19 in.	24 lb	Soviet T34
18 in.	20 - 22 lb	German Panther

(U) In the final analysis, the standoff and depth represent the conditions where immobilizations will occur 100 per cent of the time. Enough data were available to substantiate this conclusion.

4.3 Less Than 12-Pound Class

(U) The third group contained the small charges ranging from 2.5 to 10 pounds. Two reports were contained in this grouping, a study of the effectiveness of M7 mines and a comparison study of three types of explosives. Details are contained in Analytical Laboratory Report Number 60-AL-23, Appendix D.

(C) Table II of Analytical Laboratory Report 60-AL-23 indicates that the Soviet T34/85 tank is more readily immobilized by the M7 mine when detonation occurs between, rather than under, road wheels. Maximum useful standoff is not defined. This tabulation also reveals that the M7 mine broke the US single-pin track only under the most ideal circumstances. It is revealed that the US double-pin track is the most vulnerable of the three types, but again, maximum useful standoff is not well-defined. Chart 2 reveals an approximate relationship between burial depth of the M7 mine and probability of immobilizing the Soviet T34/85 tank and the US M26 (double-pin track) tank.

(C) The comparison study data had to be analyzed separately since the target used was very unique: an M47 tank fitted with Soviet JS III track. This analysis indicated two significant facts. More explosive is required to break the track under the first road wheel than under the third road wheel. The difference is approximately four pounds of Composition B. The second significant fact is that the minimum weights of the three explosives required to produce 100 per cent of immobilizations varies under the same test conditions. The weights are:

3 lb of HBX6
5 lb of Composition B
5.5 lb of TNT

The difference between 5 pounds of Composition B and 5.5 pounds of TNT may not be of any significance.

4.4 Summary of Results

(U) For the purpose of comparing explosive weights, a parameter known as the "Lethal width of the charge" will be used. This is defined as a measure of the range over which the charge will immobilize a tank.

(C) For the heavy charges, the tank is vulnerable over its entire width, plus some distance to either side. The maximum effective standoff is measured from the charge to the centerline of the tank and is the maximum distance at which a successful immobilization is known to have occurred (see Figure 8). The lethal width is the sum of the maximum effective standoff to the right of the charge and the maximum effective standoff to the left of the charge. Since these two maximum standoffs are equal, the lethal width is also either maximum effective standoff multiplied by two.

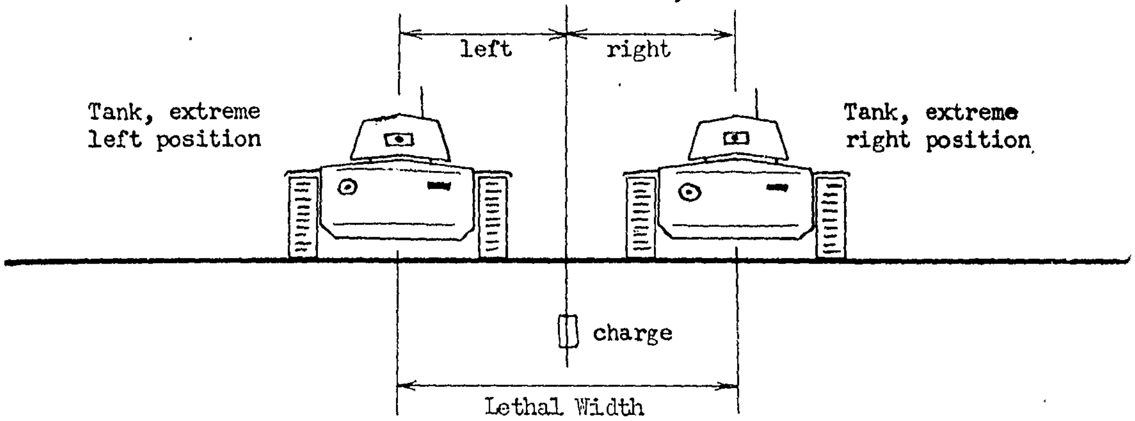

Figure 8 (C): Determination of Lethal Width for Charge Weights of 35 Pounds and Above.

(C) For charges of 24 pounds or less, the attack is usually directed against the track. Therefore, standoff distances are most significant when measured from the track centerline to the charge. A given charge usually inflicts somewhat greater damage when detonated inboard of the track centerline. This sometimes results in a larger maximum standoff inboard than outboard. For the purpose of determining the lethal width of the charge, only the outboard standoff will be used. This will insure immobilization whether detonation occurs outboard or inboard. For charges of 24 pounds or less, the lethal width will be the maximum outboard standoff times four. This takes into account both sides (inboard and outboard) of two tracks. Figure 9 is the specific example of a 12-pound M6 mine versus US double-pin track.

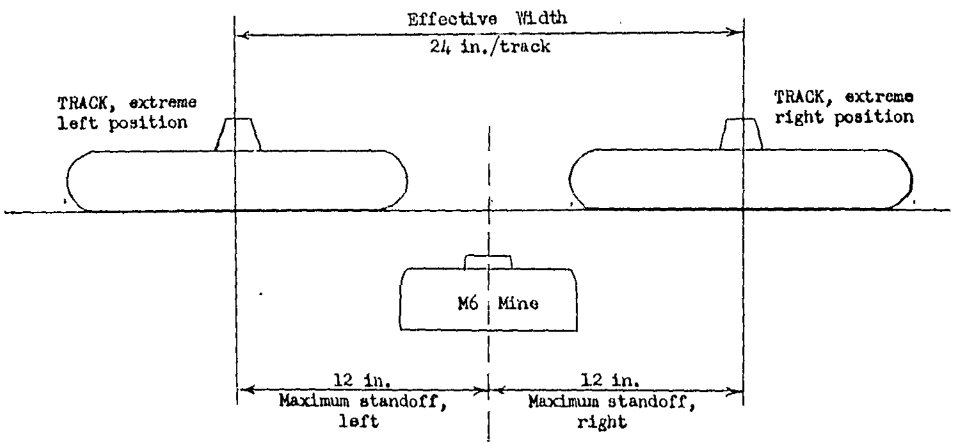

Figure 9 (C): Determination of Lethal Widths for Charge Weights of 24 Pounds or Less.

The lethal widths in this weight group indicate the position where immobilizations will occur 100 per cent of the time.

(C) In Table I are the conditions plotted on the graph in Figure 10. For the charges larger than 24 pounds, the lethal width is double the maximum effective standoff. For charges less than 24 pounds, the lethal width is quadruple the maximum effective outboard standoff.

Table I. (C) Plotted Conditions

Explosive Weight, pounds	Maximum Standoff, inches	Lethal Width, inches	Burial Depth, inches
216	150	300	72
	138	276	72
	132	264	81
	96	192	96
108	[a]132	264	63
	120	240	63
	102	204	65
46	100	200	20
	88	176	20
	88	176	30
40	93	186	44
	77	154	44
	93	186	31
35	64	128	10,20,30
24	17	68	3
12	12	48	3

[a]Damage severe but reparable - target did not overturn.

5. DISCUSSION

5.1 (C) Results

The graph of Lethal Width versus Explosive Weight, Figure 10, plotted using results from the previous tabulation, closely fulfills expectations.

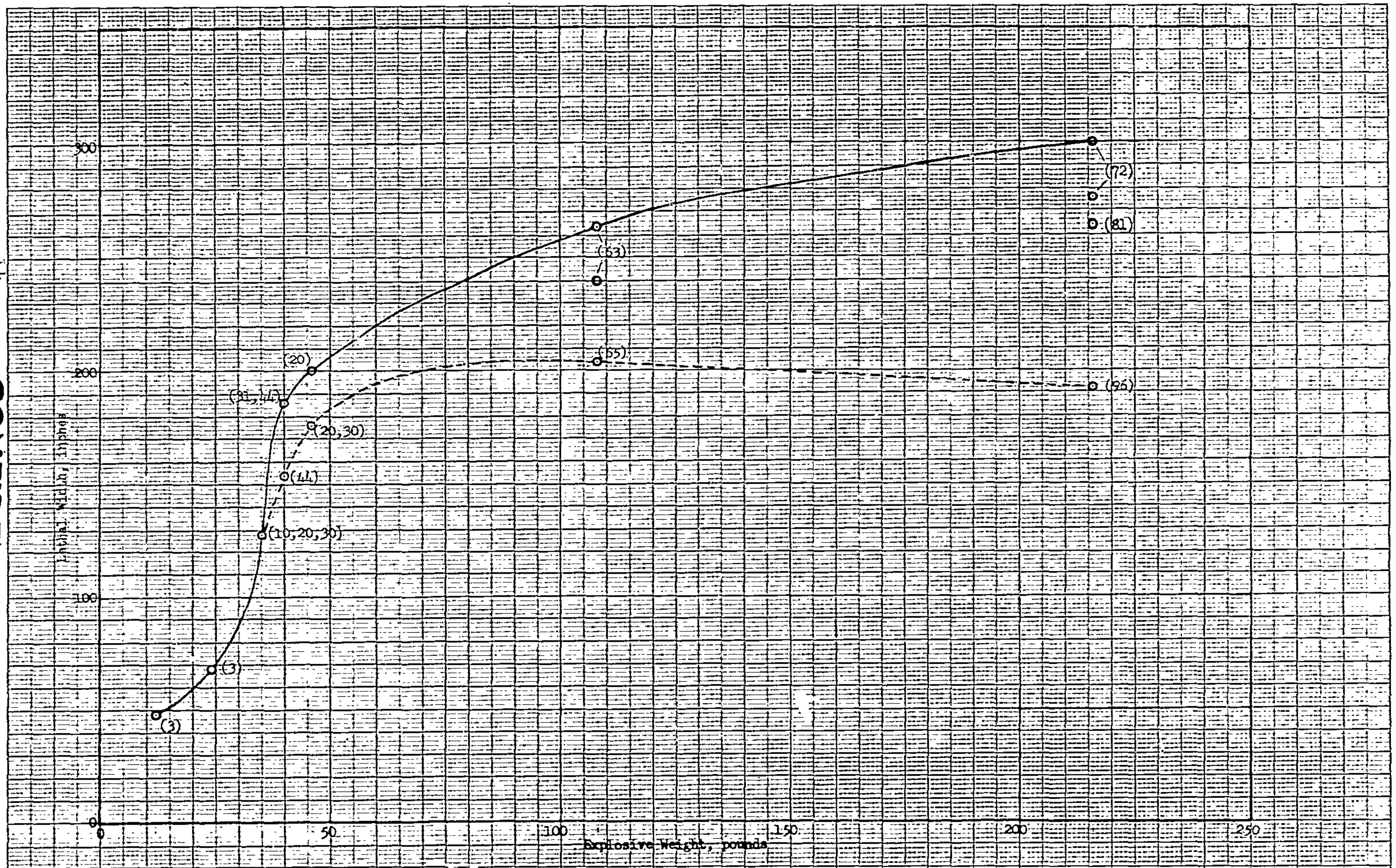

Figure 10. Explosive Weight versus Lethal Width. Burial depths (inches) in parenthesis. All targets were United States tanks, M4, M26 with double-pin track.

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Damage in the area of the two lower points is almost exclusively track damage. These points are well-defined for the particular charge/target combinations used and they indicate conditions that produce immobilizations 100 per cent of the encounters. As the explosive weight increases, less coverage of the explosive charge is required to break the track. Then, with only a slight increase in weight, the belly armor becomes vulnerable and the lethal width of the charge increases rapidly. However, the conditions no longer indicate the positions of 100 percent immobilizations. Instead, they indicate the range of conditions for which immobilizations are known to have occurred.

Beyond this near-vertical portion of the curve, another slope change occurs. This is where the increasingly heavy charges begin to overturn the tank from increasingly larger standoffs. Again, only a range where immobilizations have occurred is depicted. As indicated by the slope of the upper portion of the graph, a great price must be paid in terms of explosive weight increase.

Extrapolation of the curve beyond its upper limit should cause it to approach a horizontal line. In this region of high lethal widths a tremendous explosive weight is necessary to destroy the tank. Extrapolation of the curve beyond its lower limit should result in an extreme slope change, becoming almost vertical and intersecting the abscissa at some positive value, since there is some definite minimum weight that will break the track. Below this weight, immobilization will not occur and the lethal width of the charge will be zero while there is still a positive weight of explosive.

The lower (dashed line) curve is included only to indicate the lower limit of the range of lethal widths covered by the investigation.

It must not be assumed that a charge within the weight range covered by Figure 10 will necessarily have the lethal width indicated by the curve with a high probability of immobilization. The type of target, the type of explosive, the soil condition and the burial depth of the charge may have to be considered. With regard to charge burial depth, Figure 11 has been prepared to indicate an approximate relationship between burial depth and lethal width for explosive weights from 35 to 216 pounds. Unfortunately, the range of burial depths for any given charge weight is small.

5.2 (U) Limitations

While the graph in Figure 10 provides a basis for explosive weight selection, its widespread application is limited. Data used in constructing this graph came from charges detonated against US M4 and M26 tanks only. Both are obsolete, but the results can still be applied to modern tanks in the same weight group. However, the results cannot be applied to either heavier or lighter tanks with any degree of reliability.

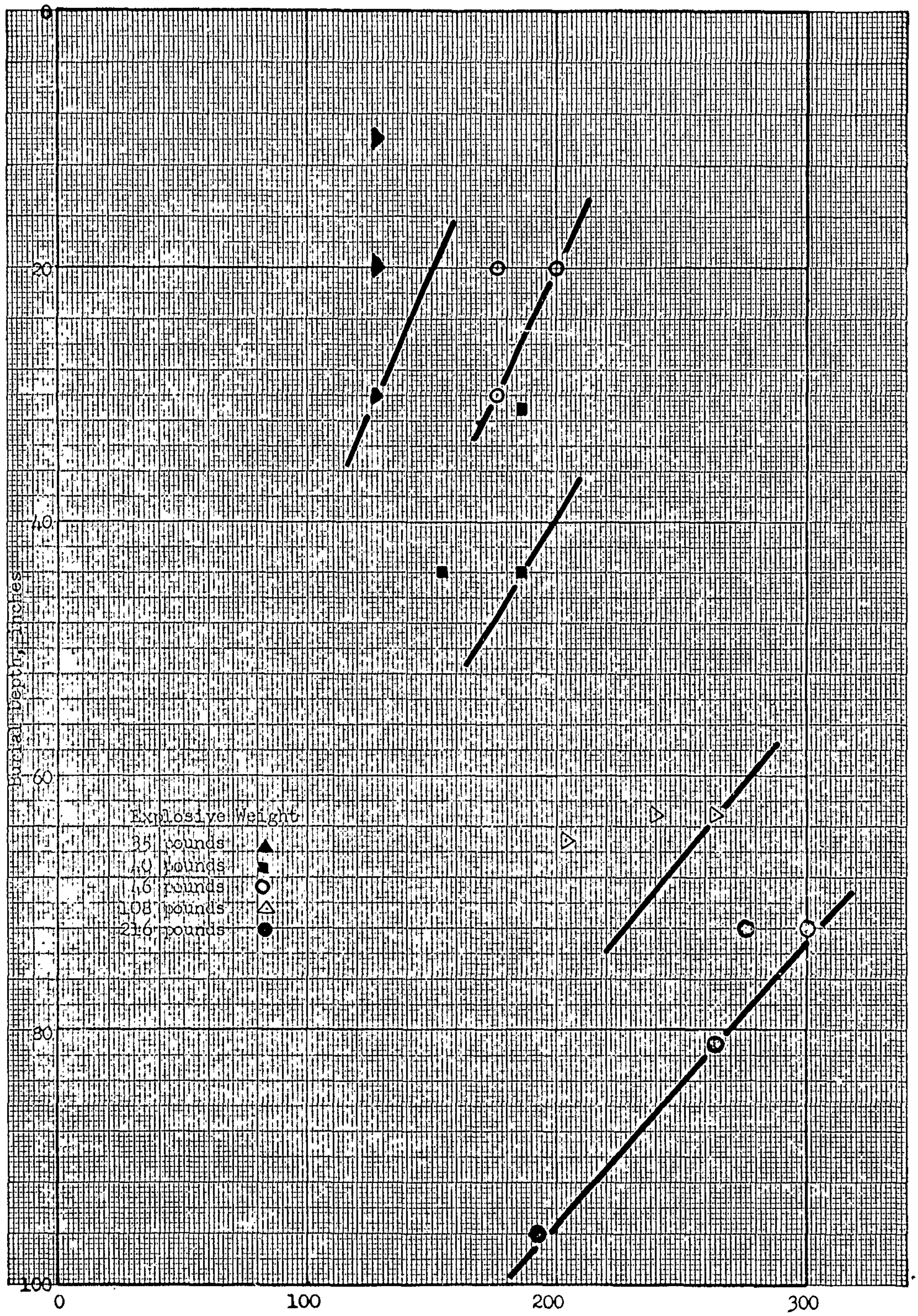

Figure 11: Lethal Width Versus Burial Depth.

In the area where track damage is predominant, all results were obtained using US double-pin track. It cannot be construed that the findings of this report can accurately be applied to other types of track, such as single pin, both US and Soviet.

In the upper region of the graph, the heavy charges used in overturning the tanks were cast TNT discs. This explosive is the reference for rating the strength of other explosives. Therefore, others will be more or less effective depending on their power, relative to TNT. This limitation must be imposed on the use of the results of this survey.

Possibly the omission of soil-condition variations could impose another limitation on the use of this survey's results. By necessity, the effect of variations in soil condition had to be neglected. Future tests may indicate that soil condition is a definite factor.

6. CONCLUSIONS

It is concluded that:

a. (C) The minimum weight that will produce immobilization is 3 pounds of HBX6, 5 pounds of Composition B, or 5-1/2 pounds of TNT. These charges were all detonated on the centerline of the track directly under an intermediate road wheel. The track was Soviet JS III, reputed to be one of the strongest available for testing.

b. (C) Belly armor similar to that of the US M4 and M26 becomes vulnerable in the explosive weight range of 25 to 35 pounds.

c. (C) The minimum charge weight that will overturn a vehicle in the US M26 weight class is 35 pounds. However, standoff and depth combinations are not sufficiently substantiated to conclude the range over which the overturning will occur.

d. (U) The limitations of the findings of this survey indicate several sets of standards need to be established. This applies to damage assessment procedures and the consideration of soil condition.

7. (U) RECOMMENDATIONS

It is recommended that:

a. The former practice of complete damage assessment by qualified personnel, in terms of per cent loss of mobility and firepower, and man-hours for repair, should be resumed.

b. Where practical, future tests should be conducted with operational vehicles and damage should be completely repaired subsequent to each firing, thereby minimizing the possibility of cumulative damage.

c. Provisions be made in future tests to consider soil conditions. Basically, this means categorizing the elementary soil types and establishing standard nomenclature.

d. Future tests in this field of study be conducted with a secondary objective of supplementing this survey.

SUBMITTED:

Paul E. Kertis

P. E. KERTIS
Test Director

REVIEWED:

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Claude E. Brown

C. E. BROWN
Chief, Infantry and
Aircraft Weapons Division

APPROVED:

H. A. Noble

H. A. NOBLE
Assistant Deputy Director
for Engineering Testing
Development and Proof Services

REFERENCES (U)

The data for this survey were compiled from the following sources:

Firing Records -

No. AR-19340	No. P-64338
19288	61717
18565	54301
18536	48330
18505	
18198	
17629	
17488	
17429	
17287	

Armor Development Report No. AD-1154 and No. AD-1153.

BRL Memorandum Report No. M-1141 and No. M-616.

Project Doan Brook Technical Memorandum No. 22 - APGC-TN-58-42.

APPENDICES (U)

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APPENDIX A
Correspondence

ORDNANCE CORPS
PICATINNY ARSENAL
DOVER, NEW JERSEY

Mr. A.Stern/nnd/2190

IN REPLY
REFER TO:

FELTMAN RESEARCH AND ENGINEERING LABORATORIES
ORDBB- TF3

APR 2 '59 -9 AM

SUBJECT: Effectiveness of HE Blast Charges as AT Mines (U)

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
ATTENTION: D&PS

1. (C) This Arsenal is interested in data on the effectiveness of HE blast charges when used as mines against tanks and armored vehicles. Such information enables the designer to make the most efficient and economical choice of explosive charges and permits detailed comparative analysis of complete round effectiveness. This information is particularly desired in connection with a current feasibility study of remotely emplaced mine systems, and may be of considerable use in connection with other mine weapon systems.

2. (C) Your Proving Ground has conducted the majority of such vulnerability tests in this country. Considerable data is available in the various APG firing records, some of it is understood to be unpublished. It is considered highly advantageous to have the available data compiled and analyzed in terms of effectiveness and considering such parameters as charge weight and composition, burial depth and location with respect to target. Both belly and track attack are to be considered, with every effort to correlate the damage to currently operational armored vehicles and tanks.

3. (U) In view of the broad experience of your personnel in this field it is requested that the available data both published and unpublished be compiled, analyzed and published in one report. It is therefore requested that your agency submit an estimate of time and funds for completing such a report together with any applicable suggestions or comment.

FOR THE COMMANDER:

J.H. Robinson

J. H. ROBINSON
Assistant

AC RD 59-1416

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Deferred

X DA

CG ABERDEEN PG MD

CO PICATINNY ARSENAL, DOVER, N.J.

UNCLAS For ORDBB-TF3 Stern from ORDBG-DP-DP Stecher Sgd Jones.

7496

1. Cost estimate to conduct Survey of Effectiveness of H.E. Blast Charges as AT Mines as outlined in your letter dated 27 March 1959 is $5,500.00.

2. Breakdown of cost estimate being forwarded by mail. Request reply by TT on your decision to conduct survey.

Comeback Copy:
Pvt. Paul E Keatis
Term. Effect.
B-345

5 June 1959 1700 Z

ORDBG-DP-DP

N. T. Stecher
32279 1 1

H. D. JONES
Chief, Program Planning Office
Development and Proof Services

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APPENDIX B
Analytical Laboratory Report 60-AL-26
16 February 1960

Title: Immobilization of Tanks by High Explosive Charges

Prepared for: Terminal Effects and Special Projects Br., Inf and Acft Wpns Div

Project No.: TS1-200/01

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1. (C)The attached table summarizes the results of detonations of heavy charges of high explosive placed at various depths and distances from tanks. The weight of explosive ranged from 35 to 216 pounds. Thirty-six detonations were made against the M4 Tank and 21 against the M26. Charts 1 and 2 show the location of the charges relative to a point on the surface of the ground directly beneath the center of gravity of the tank. The charts also show which detonations immobilized the tank.

2. (C)These data were examined to see whether relationships between percentage of tanks immobilized and the different variables--charge weight, burial depth, and standoff--could be established. Unfortunately the data are not suited to this type of analysis. The principal shortcoming is that the effects of different weights of charge and different burial depths are not separable. Apparently, most of the data were collected from tests whose purpose was to examine the effect of variation of standoff for a particular combination of burial depth and weight of charge. The charts show the situation rather clearly.

3. (U)Ideally the type of relationship that would be desired from such data would be the probability of immobilization as a function of charge weight, burial depth, and standoff. A useful but much less extensive relationship would be contours of constant probability (0.5 for instance) instead of complete distributions. However, estimation of such contours requires at least two percentages (reasonably well defined) near 50% at entirely different combinations of depth and standoff for each of several charge weights (at least three) spaced over the range of interest. From the present data it would be possible to estimate only one such combination for any of the charges used. Without these minimum requirements estimation of relationships would depend heavily on assumptions or on purely theoretical considerations. The choice of reasonable and valid assumptions as well as the selection of applicable theory would require research and study beyond the scope of the present statistical examination of data.

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Table of Number of Tanks Immobilized per Number of Detonations of High Explosive Charges

M4 Tank

Weight of Charge, lb	Burial Depth, in.	Standoff in.	Proportion Immobilized	Damage Echelon
35	10	64-66	2/2	A,C
		88	0/1	
	20	64	1/1	A
		76	0/1	
	30	64	1/1	B
		76	0/1	
		88	0/2	
40	36	88	0/1	
46	10	88	0/1	
	20	88	1/1	C
		100	1/1	C
	30	88	1/1	C
		100	0/1	
54	60	0	1/1	B
	70	90	0/1	
		150	0/1	
108	63-65	78	0/1	
		90	2/2	C,B
		102	2/3	C,C
		120	0/2	
		150	0/1	
	96	90	0/1	
162	96	108	0/1	
216	72	138	1/1	C
		150	1/1	C
		162	0/1	
	81	132	1/1	C
		150	0/1	
	91	120	0/1	
	96	108	0/1	

Table (continued)

M26 Tank

Weight of Charge, lb	Burial Depth, in.	Standoff in.	Proportion Immobilized	Damage Echelon
40	28-31	0	1/1	C
		93	1/1	B
		201	0/1	
	36	0	1/1	C
		105	0/1	
		129	0/1	
	41-44	0	2/2	B,B
		77	1/1	C
		93	1/1	C
54	69	60	1/1	C
108	63	108	2/3	C,C
		120	1/2	C
		132	1/1	B
216	72	156	0/1	
	81	132	1/1	C
	96	96	1/1	C
		108	0/1	

Standoff: Distance measured along the surface of the ground from center of gravity of the tank to the center of the explosive charge.

Damage Echelon: A - track breakage only
B - severe but repairable
C - complete destruction

Chart 1. Immobilization of M4 Tank by High Explosive Charges

Standoff is the distance from center of gravity of the tank to center of the explosive charge (surface distance).

Points connected by straight-line segments represent charges of the same weight. The weight, in pounds, is as indicated.

● Detonation immobilized tank

○ Detonation failed to immobilize tank

↓ At greater standoff no portion of the tank covered the explosive

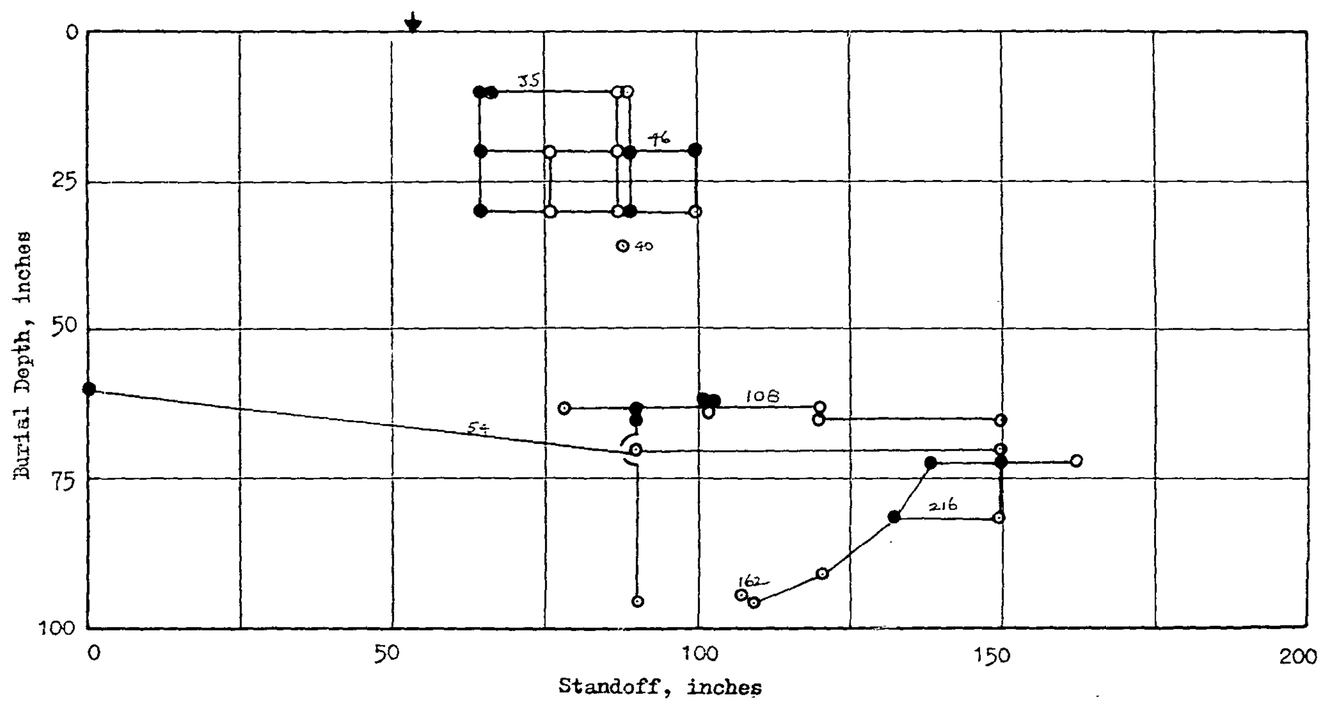

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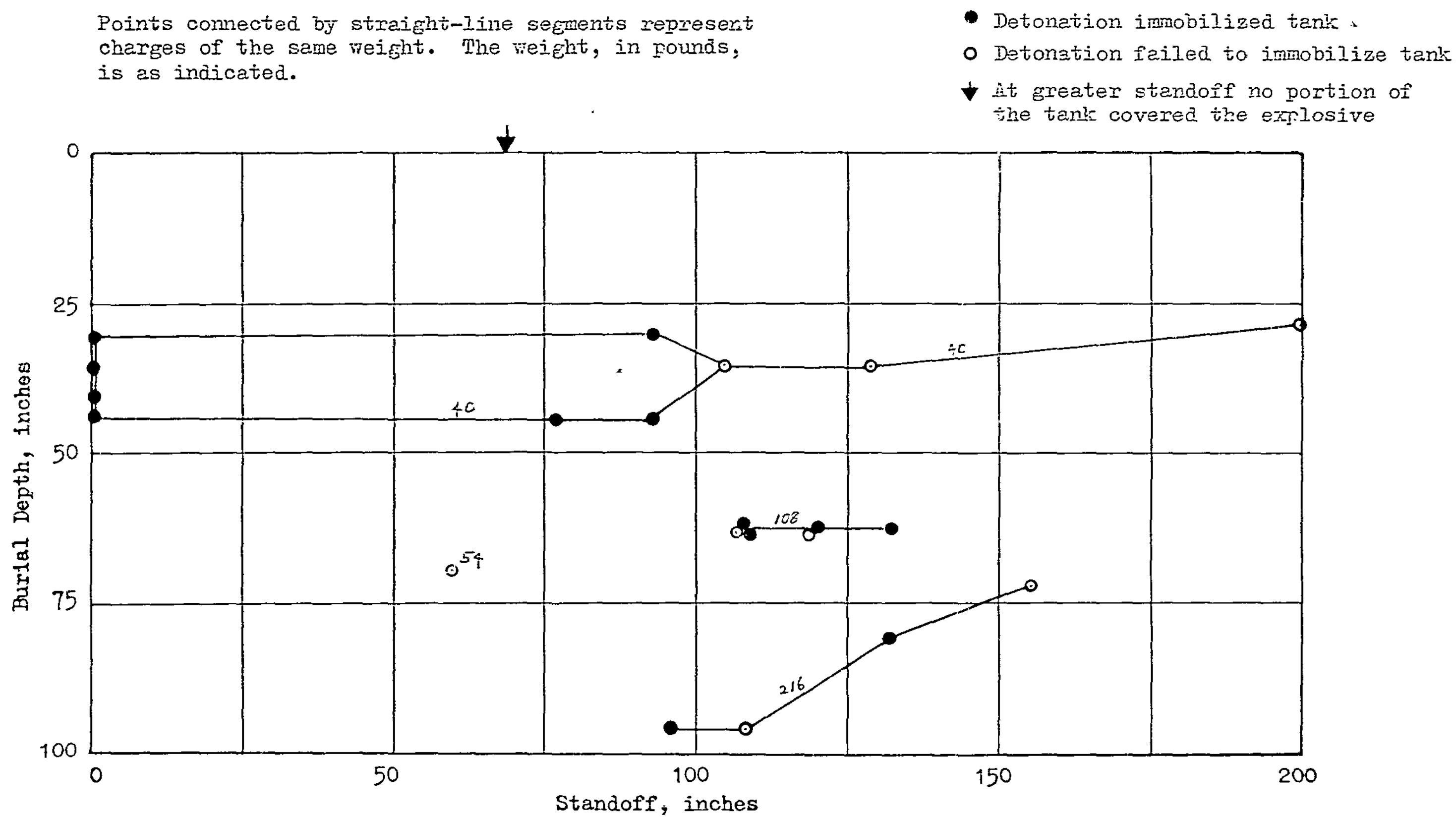
Chart 2. Immobilization of M26 Tank by High Explosive Charges

Standoff is the distance from center of gravity of the tank to center of the explosive charge. (surface distance).

Points connected by straight-line segments represent charges of the same weight. The weight, in pounds, is as indicated.



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APPENDIX C
Analytical Laboratory Report 60-AL-19
5 February 1960

Title: Immobilization of Tanks by High Explosive Charges

Prepared for: Terminal Effects and Special Projects Br., Inf and Acft Wpns Div

Project No.: TS1-200/01

1.(U) The data supplied by your office on the effect of high explosive charges against tanks were examined to see to what extent relationships between the several variables and the proportion of tanks immobilized could be found. The analysis consisted primarily of summarizing the data in various ways, comparing percents of tanks immobilized under similar conditions, and making graphs to show, where possible, the change in percent as conditions are varied. Summary tables in Inclosure 1 show for each of four classes of track the number of tanks immobilized per number of trials, by weight of explosive charge, location of the charge relative to the centerline of the track (distance inboard or outboard), and location of the charge relative to the center of a roadwheel (on line with the roadwheel or between roadwheels). A series of graphs is given in Inclosure 2.

2.(C) Because the data are sparse, statistically speaking, only rather broad or quite general comparisons could be expected to reveal differences or similarities. All results discussed below should be interpreted in that context.

a. Double-pin track.

(1) The effectiveness of the mine appeared to be unaffected by its location relative to the roadwheel--whether directly in line with the center of the wheel or between wheels.

(2) There was some indication that a mine placed outboard of the first roadwheel was less effective in immobilizing the tank than a mine placed at the same distance outboard of other roadwheels.

(3) Explosive charges detonated inboard inflicted more severe damage than those detonated outboard under similar conditions. Of the 18 inboard detonations that immobilized the tank all but 3 were classed as "severe but repairable", whereas all 21 immobilizations from detonations outboard were due to track breakage only.

b. Others. Data for the other three classes of track seemed to follow the pattern discussed above, with one exception. Mines placed outboard of the first roadwheel of the Soviet T34 were no less effective than mines at the same standoff outboard of other roadwheels. Generally, however, the data for these tanks are insufficient for making detailed comparisons.

3.(C) For each class of track the data were combined to give the proportion of tanks immobilized versus weight of explosive and standoff, inboard and outboard.

(These data are in the last two columns of the summary table.) Plots of "percent of tanks immobilized versus standoff" are given in Charts 1-4. The points were connected by straight line segments to present a sketch of the profile of effectiveness. For several reasons no attempt was made at this time to develop smooth or more refined curves to describe the probability of immobilization as a function of standoff, weight of charge, and so on. First, the effects of other variables are undoubtedly important but not estimable from these data alone. For example, the longitudinal location of the mine is ignored. Although this factor might be of little consequence for outboard detonations, it would be quite important for inboard detonations. Second, engineering considerations, operational experience, etc., should be brought in to complete the information.

4.(C) Since the interpretation of the curves in these charts is probably obvious, only a few comments on them are offered.

a. Data on the double-pin track (T26 Tank) are by far the most complete. Although inboard detonations of the 24-pound mine are few, this lack of data may not be serious for the approximate place of the curve on the graph (Chart 1) can be visualized by assuming that damage from the 24-pound mine would be at least as great as that from the 12-pound charge, and that a certain amount of symmetry about the centerline of the track would be present. The curve for the 24-pound charge is systematically displaced to the right of the curve for the 12-pound charge. This shift is unquestionably indicative of the difference in effectiveness of the two charges, but the exact location of these curves is due partly to chance and the judicious choice of intervals used in summarizing the data. Probably the most reliable measure of difference is along the 50-percent line, since the corresponding distances have the largest samples.

b. Although the data on single-pin track are scarce, they indicate that the 12-pound charge at standoff distances (outboard) of 12 to 18 inches is less effective against the single-pin track than against the double-pin track. The difference can be seen by superimposing Chart 1 on Chart 2.

c. A similar comparison of Chart 3 (Soviet T34) with Chart 1 shows approximate coincidence of the curves for the 24-pound charge, but a difference between the curves for the 12-pound charge. If the two charts are superimposed so that points on the standoff scale corresponding to the edge of the track are in coincidence, the curve for the T34 lies to the left, i.e., equal percentages require smaller standoff. The difference is about 3 inches along the 50-percent line.

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Summary Table

Number of Tanks Immobilized per Number of Detonations
(all mines buried to a depth of 3 inches except as noted)

Weight of Explosive, lb	Stand-off, in.	Location of Mine Relative to Roadwheels: Center IB	Center OB	Ctr No. 1 IB	Ctr No. 1 OB	Between IB	Between OB	Total IB	Total OB
				Double-Pin Track[a]					
12	11–13	3/3	4/4					3/3	4/4
	14–17	2/2	3/5		0/3		4/4	2/2	7/12
	19–22	1/5	1/5	2/3			0/2	3/8	1/7
	26	1/4		1/1				2/5	
	41	1/2						1/2	
	57	1/1		2/2				3/3	
24	13	1/1	1/1	2/2				3/3	1/1
	17	1/1	1/1					1/1	1/1
	21–24		4/8				1/2		5/10
	25–29		2/6		0/1		0/3		2/10
				Single-Pin Track					
12	11–13	1/1	0/1					1/1	0/1
	14–17		0/1		0/1		0/3		0/5
	21		0/1						0/1
24	21–23		0/3				0/2		0/5

Standoff: distance from track centerline to center of mine.
IB, OB: inboard or outboard from track centerline.
Center and Center No. 1: mine placed on line with center of roadwheels. Column headed Center includes data for all roadwheels except the first.
Between: mine placed on line halfway between roadwheels.

[a]All but 3 inboard detonations that immobilized the tank inflicted "severe but repairable" damage; all immobilizations from outboard detonations were due to track breakage.

Summary Table (Continued)

Number of Tanks Immobilized per Number of Detonations

(all mines buried to a depth of 3 inches except as noted)

Weight of Explosive, lb	Stand-off, in.	Location of Mine Relative to Roadwheels: Center IB	Center OB	Ctr No. 1 IB	Ctr No. 1 OB	Between IB	Between OB	Total IB	Total OB
					T34 Soviet Tank				
12	0				1/1				1/1
	10–11		2/4	0/1	1/2			0/1	3/6
	12–13	1/1	0/1		0/2		3/4	1/1	3/7
	16						0/1		0/1
24	19		1/1					1/1	
	22–23		1/4				0/2		1/6
	24–25		0/2				0/1		0/3
					German Panther				
20–22	13–14[a]		1/1		1/1	1/1		1/1	2/2
	18		1/1		1/1				2/2
	24		0/2						0/2
	36		0/2[b]		0/2[b]				0/4
	42		0/2						0/2
	48				0/2				0/2

[a]Mines buried 6 inches.
[b]One mine buried 6 inches.

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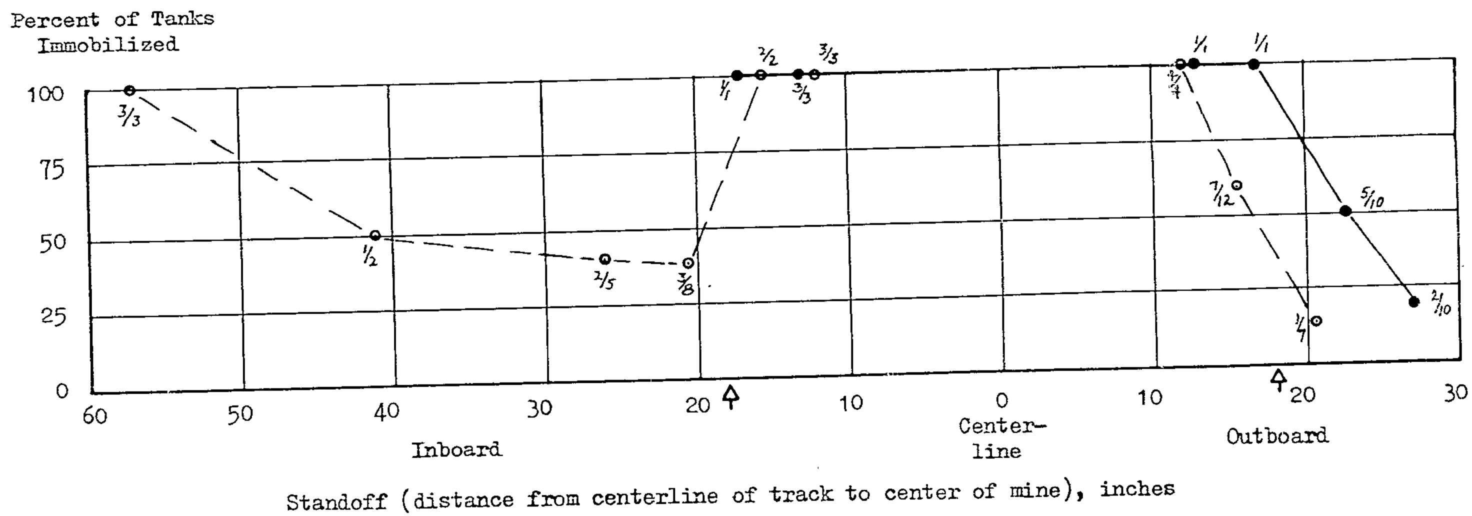
Chart 1. Immobilization of Tanks by High Explosive Charges - Double-Pin Track
(all mines buried to a depth of 3 inches)

The fraction a/b beside a plotted point indicates a tanks immobilized in b trials.

- o 12-lb mine
- ● 24-lb mine
- At greater standoff no part of the track covered the mine.



Incl 2

Chart 2. Immobilization of Tanks by High Explosive Charges - Single-Pin Track
(all mines buried to a depth of 3 inches)

The fraction a/b beside a plotted point indicates a tanks immobilized in b trials.

o 12-lb mine

● 24-lb mine

At greater standoff no part of the track covered the mine.

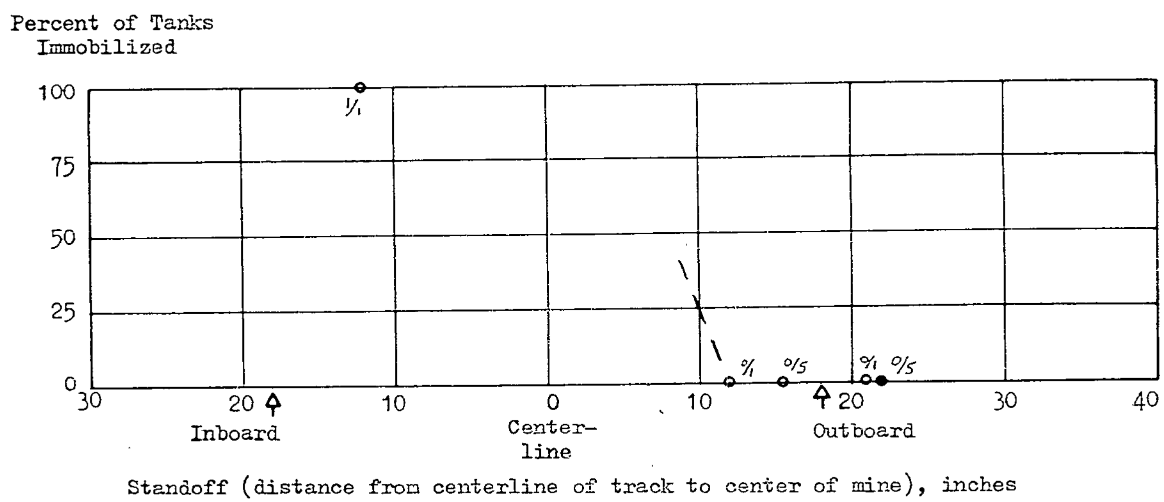


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Chart 3. Immobilization of Tanks by High Explosive Charges - Soviet Tank, T34
(all mines buried to a depth of 3 inches)

The fraction a/b beside a plotted point indicates a tanks immobilized in b trials.

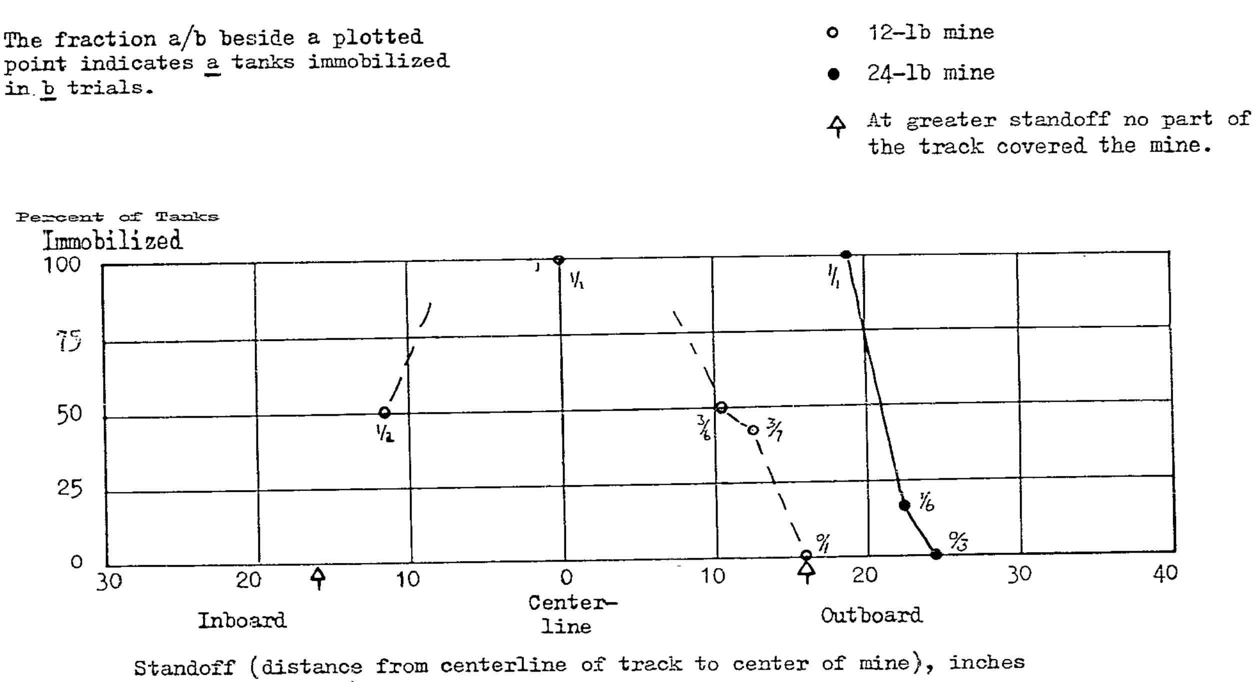
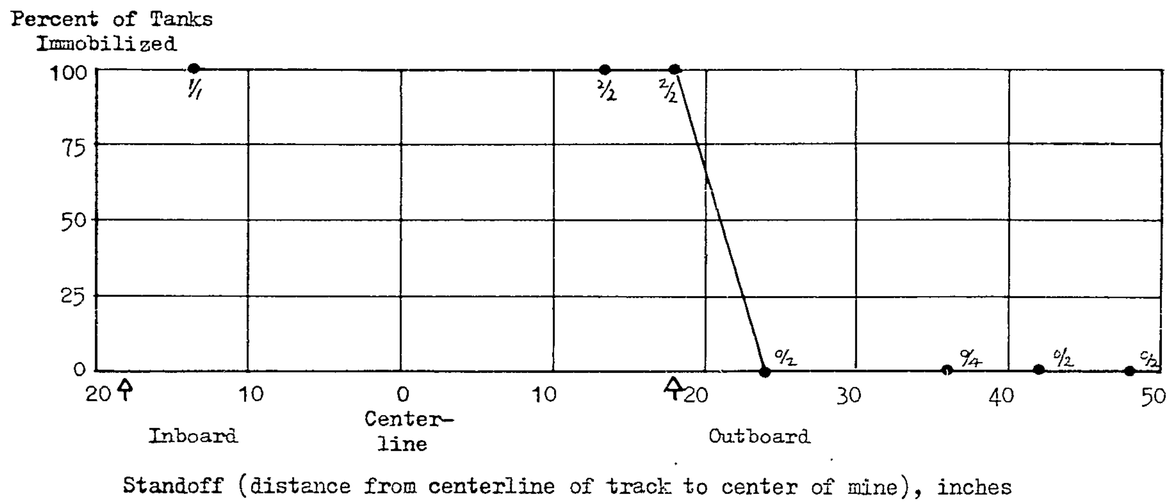


Chart 4. Immobilization of Tanks by High Explosive Charges - German Panther
(all mines buried to a depth of 3 inches except as noted)

The fraction a/b beside a plotted point indicates a tanks immobilized in b trials.

● 20 or 22-lb mine

At greater standoff no part of the track covered the mine.



Note: The 3 mines at 13–14 in. and 2 mines at 36 in. **were** buried to a depth of 6 inches.

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APPENDIX D

Analytical Laboratory Report 60-AL-23
12 February 1960

Title: Immobilization of Tanks by High Explosive Charges

Prepared for: Terminal Effects and Special Projects Br., Inf and Acft Wpns Div

Project No.: TS1-200/01

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1. (U) Two groups of data supplied by your office on the effect of explosive charges against tanks were analyzed to obtain, where possible, relationships between the percent of tanks immobilized and the variables included in the tests. Summaries of the data are given in Tables I and II, and graphs of selected results are given in Charts 1 and 2. The paragraphs that follow discuss briefly the results.

2. (C) US M47 Tank fitted with Soviet JS-3 Track. In this series of 25 detonations of explosive charges against the JS-3 Track three different explosives, Composition B, TNT, and HBX6, were used in varying amounts. Results are summarized in Table I and graphed in Chart 1. The graphs show the proportion of tanks immobilized as a function of weight of explosive charge.

a. Charges of Composition B were placed beneath the first roadwheel and beneath the third roadwheel. A cursory comparison of the two sets of data indicates that a much greater charge is needed to immobilize the tank if the explosive is beneath the first roadwheel. Closer examination of the data shows that only one detonation under the first roadwheel failed to immobilize the tank. Consequently, just how much greater if any the charge must be if placed under the first roadwheel is not precisely determined. Five or more pounds detonated under the third wheel appears to be sufficient to immobilize the tank, and 9 or more pounds detonated under the first wheel is sufficient. The data do not show conclusively that 9 pounds are needed; some smaller amount might suffice.

b. Charges of TNT and HBX6 were detonated beneath the third roadwheel. Results for the TNT charges were similar to results for the Composition B similarly placed. The plot shows the TNT curve to the right by a small amount that is not statistically sifnificant, implying that they could be alike for all we know. The curve for the HBX6 charges, however, is shifted to the left of the curves for Composition B and TNT, indicating that a smaller charge is required for immobilizing the tank under these conditions.

3. (C) 3.5-pound charges of tetrytol. About 60 detonations of 3.5-pound charges of tetrytol placed at various depths and standoff distances were made against various targets. The data are summarized in Table II and graphed in Chart 2.

a. Mines placed between roadwheels of the Soviet T34 immobilized the tank more often than mines placed in line with the center of a wheel. For depths up to 12 inches, 4 out of 4 detonations between roadwheels broke the track, but none in 7 detonations in line with the wheels immobilized the tank. This comparison might overestimate the difference, because 4 of the 7 were in line with the first roadwheel--a location that possibly requires a greater charge to break the track. However, even if those 4 are excluded, the difference between 0 in 3 and 4 in 4 is still statistically significant.

b. For the M26 Tank, double-pin track, the mines placed between roadwheels gave a slightly higher percentage of immobilizations, but the difference is not statistically significant.

c. Although a relationship between percent of tanks immobilized and burial depth cannot be precisely determined from these data, a sketch of the data suggesting a relationship is given in Chart 2. Because of the differences discussed in a and b, above, and because the number of detonations at various depths was not the same for "center" and "between", those data could not be combined without obviously distorting the results. Certain combinations seemed reasonable and were resorted to in order to make the graph.

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Table I. Number of Tanks Immobilized per Number of Detonations
US M47 Tank Fitted with Soviet JS-3 Track

(all explosive charges were located under the centerline of the track and buried to a depth of 3 inches)

Explosive	Longitudinal Position of Chg, Roadwheel No.	Weight of Charge, lb	Proportion of Tanks Immobilized	Damage Echelon[a]
Comp. B	1	9.54	1/1	B
		8.95-9.03	3/3	B,B,A
		8.05	0/1	
Comp. B	3	7.94	1/1	B
		6.99	1/1	B
		4.96-5.07	3/3	B,B,A
		4.46-4.57	1/2	A
		4.07	0/1	
TNT	3	5.56	1/1	A
		4.91-5.04	3/4	A,A,A
HBX6	3	4.57	1/1	A
		3.59	1/1	A
		2.97-3.07	3/3	A,A,A
		2.50-2.55	0/2	

[a]Damage echelon of tanks immobilized:
A - track breakage only
B - severe but repairable

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Table II. Proportion of Tanks Immobilized by 3.5 pounds of Tetrytol Placed at Various Depths and Distances from Track Centerline

Standoff, in.	Burial Depth, in.	Location of Charge Relative to Roadwheels: Center	Location of Charge Relative to Roadwheels: Between
		M26 Tank, Double-Pin Track	
9	9	3/9	
	12	1/3	6/12
	15	0/1	
	18		0/5
12	3		2/2
14	3		0/1
		T26 Tank, Single-Pin Track	
0	3	0/1	1/1
10	3		0/1
	12		0/2
12	3		0/1
	12		0/1
		Soviet Tank, T34/85	
8	3	0/3[a]	
	9	0/1	
	12	0/3[a]	4/4
	15		1/2
	18		0/3
10	3		1/1
	12		0/1

Standoff: Distance outboard from track centerline to center of charge.
Center: Charge placed on line with center of roadwheels.
Between: Charge placed on line halfway between roadwheels.

Note: All immobilizations were due to track breakage.

[a]Two detonations at each depth were in line with the first roadwheel.

Chart 1. Effectiveness of Various Explosives against US M47 Tank Fitted with Soviet JS-3 Track
(all charges under centerline of track and buried to a depth of 3 inches)

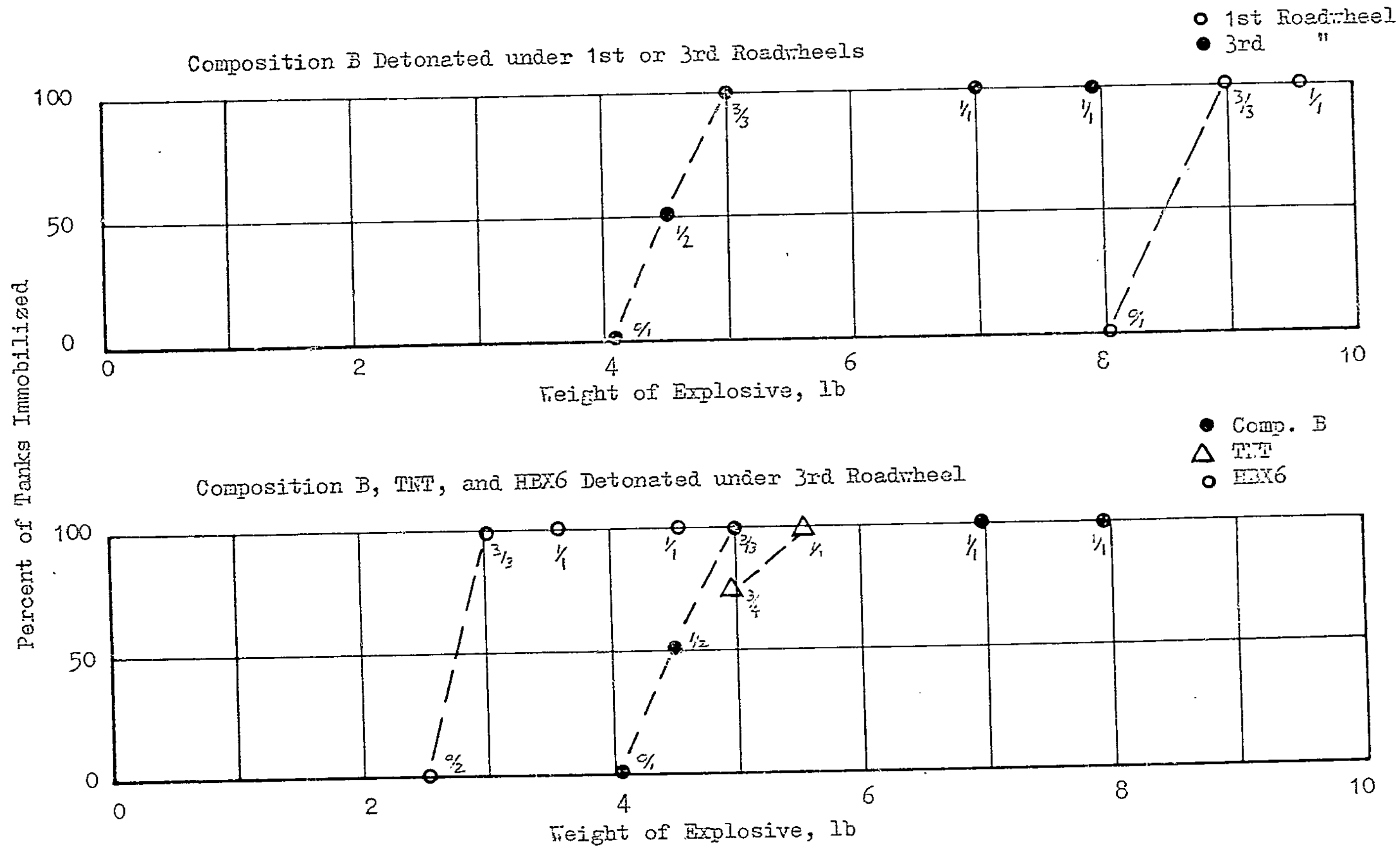

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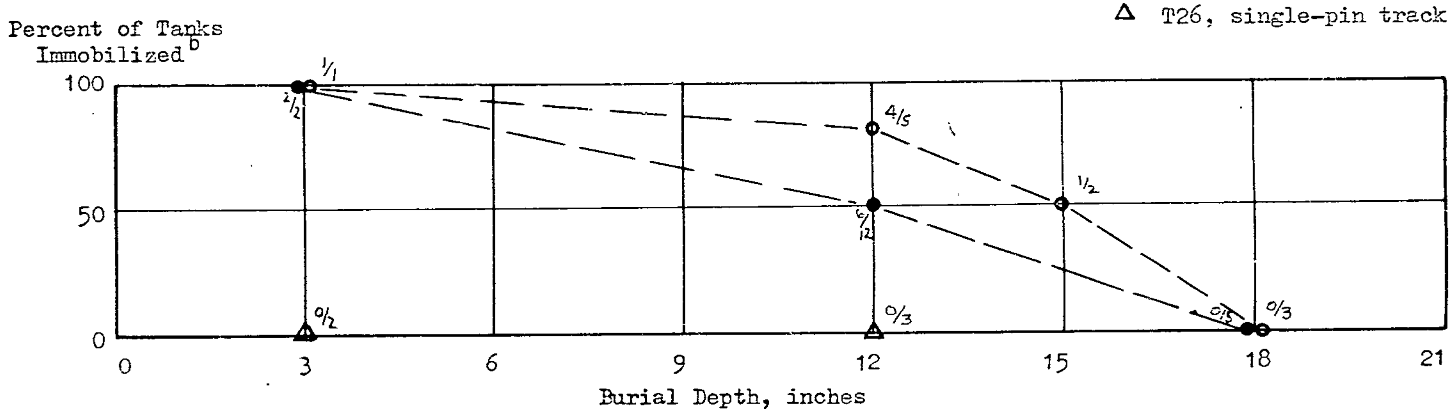
Chart 2. Effectiveness of 3.5-pound Charges of Tetrytol at Various Burial Depths
(all charges placed on a line halfway between roadwheels)

Standoff[a], in.
Soviet T34: 8, 10
US M26: 9, 12
US T26: 10, 12



[a]All distances are outboard of the track centerline.
[b]All immobilizations were by track breakage.

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